

## **Annex WP6-A**

### **EOLI-Questionnaire Sensors and Actuators**

Please provide a table for each equipment installed in your reactor. We did not include a table for the hardware sensors developed in WP3, but may be André and Nicola can help us to define some abnormal conditions with the new equipments which can be considered in the WP6 and WP7 (Development of the Fault Diagnosis and Isolation System and Supervision system development).

We classified 3 fault levels for each equipment and the rate indicates the number of occurrences of the fault during the reactor operation hours (#fault/hr).

The levels are:

- 1) “**Fuzzy**” means that the behavior is abnormal but still reasonable (noisy or spectrum out of shape)
- 2) “**Confuse**” (creasy) means that it is evident that the behavior is substantially abnormal, but the duration of this condition is too short to diagnostic the fault or the fault is intermittent.
- 3) “**Blind**” means the signal has not relation with any expected value and this effect persists during a long time.

The working months means the number of total months which the equipment has been used without maintenance or replacement.

The rows of the tables indicate the most common faults for each equipment, but if an important case is missing, please don't hesitate to add a row that describes the condition. If you think we missed important cases or you don't understand what we want, please give us a comment about it.

## 1. Faults in Sensors and Transmitters

1.1. PH, type of sensor \_\_\_\_\_ Manufacturer \_\_\_\_\_  
installed in \_\_\_\_\_

| Effect or Fault               | Fuzzy Rate | Confused Rate | Blind Rate | Working months |
|-------------------------------|------------|---------------|------------|----------------|
| Lost power                    |            |               |            |                |
| Transmitter disconnected      |            |               |            |                |
| Lost temperature compensation |            |               |            |                |
| Dirty membrane                |            |               |            |                |
| Cracked membrane              |            |               |            |                |
| Broken Electrode              |            |               |            |                |
| Drift                         |            |               |            |                |
| Human                         |            |               |            |                |
| Worn-out                      |            |               |            |                |
| Unknown                       |            |               |            |                |
| Others/describe _____         |            |               |            |                |
| General remarks _____         |            |               |            |                |

1.2. Dissolved Oxygen, type of sensor \_\_\_\_\_ Manufacturer \_\_\_\_\_  
installed in \_\_\_\_\_

| Effect or Fault                      | Fuzzy Rate | Confused Rate | Blind Rate | Working months |
|--------------------------------------|------------|---------------|------------|----------------|
| Lost power                           |            |               |            |                |
| Disconnected transmitter             |            |               |            |                |
| Lost temperature compensation        |            |               |            |                |
| Dirty membrane                       |            |               |            |                |
| Cracked Membrane                     |            |               |            |                |
| Broken Electrode                     |            |               |            |                |
| Drift                                |            |               |            |                |
| Human                                |            |               |            |                |
| Worn-out                             |            |               |            |                |
| Unknown                              |            |               |            |                |
| Reading out of the normal conditions |            |               |            |                |
| Others/describe _____                |            |               |            |                |
| General remarks _____                |            |               |            |                |

1.3. Temperature, type of sensor \_\_\_\_\_ Manufacturer \_\_\_\_\_  
installed in \_\_\_\_\_

| Effect or Fault                                    | Fuzzy Rate | Confused Rate | Blind Rate | Working months |
|----------------------------------------------------|------------|---------------|------------|----------------|
| Lost power                                         |            |               |            |                |
| Disconnected transmitter                           |            |               |            |                |
| Open circuit in the transducer                     |            |               |            |                |
| Leak of the thermal fluid (thermocouple)           |            |               |            |                |
| Thermal well dirty or debris filled (thermocouple) |            |               |            |                |
| Drift                                              |            |               |            |                |
| Human                                              |            |               |            |                |
| Worn-out                                           |            |               |            |                |
| Unknown                                            |            |               |            |                |
| Others/describe _____                              |            |               |            |                |
| General remarks _____                              |            |               |            |                |

1.4. Flow rate meter, type of sensor \_\_\_\_\_ installed in \_\_\_\_\_

| Effect or Fault       | Fuzzy Rate | Confused Rate | Blind Rate | Working months |
|-----------------------|------------|---------------|------------|----------------|
| Lost power            |            |               |            |                |
| Drift                 |            |               |            |                |
| Human                 |            |               |            |                |
| Worn-out              |            |               |            |                |
| Unknown               |            |               |            |                |
| Others/describe _____ |            |               |            |                |
| General remarks _____ |            |               |            |                |

1.5. Level, type of sensor \_\_\_\_\_ Manufacturer \_\_\_\_\_  
 installed in \_\_\_\_\_

| Effect or Fault                                     | Fuzzy Rate | Confused Rate | Blind Rate | Working months |
|-----------------------------------------------------|------------|---------------|------------|----------------|
| Lost power                                          |            |               |            |                |
| Disconnected transmitter                            |            |               |            |                |
| Lost temperature compensation (sonic or ultrasonic) |            |               |            |                |
| Receptor dirty (sonic or ultrasonic)                |            |               |            |                |
| Plates dirty (capacitor sensor)                     |            |               |            |                |
| Inappropriate tank ground (capacitor sensor)        |            |               |            |                |
| Sewage flow out of the reactor                      |            |               |            |                |
| Sewage reach erroneous level                        |            |               |            |                |
| Human                                               |            |               |            |                |
| Worn-out                                            |            |               |            |                |
| Unknown                                             |            |               |            |                |
| Drift                                               |            |               |            |                |
| Others/describe _____                               |            |               |            |                |
| General remarks _____                               |            |               |            |                |

1.6. Light intensity, type of sensor Optic installed in \_\_\_\_\_ (LBE)

| Effect or Fault | Fuzzy rate | Confuse Rate | Blind Rate |
|-----------------|------------|--------------|------------|
| Dirty           |            |              |            |
| Worn-out        |            |              |            |
| Human           |            |              |            |
| Unknown         |            |              |            |
|                 |            |              |            |

## 2. Faults in Actuators

2.1. Servo-valve, type of actuator \_\_\_\_\_ Manufacturer \_\_\_\_\_  
installed in \_\_\_\_\_

| Effect or Fault                         | Fuzzy Rate | Confused Rate | Blind Rate | Working months |
|-----------------------------------------|------------|---------------|------------|----------------|
| Signal conversion stage failed          |            |               |            |                |
| Modulator system disconnected or failed |            |               |            |                |
| Valve Not moving                        |            |               |            |                |
| Not closing fully                       |            |               |            |                |
| Not opening fully                       |            |               |            |                |
| Movement sluggish                       |            |               |            |                |
| Human                                   |            |               |            |                |
| Worn-out                                |            |               |            |                |
| Unknown                                 |            |               |            |                |
| Others/describe _____                   |            |               |            |                |
| General remarks _____                   |            |               |            |                |

2.2 Pump, type of actuator \_\_\_\_\_ Manufacturer \_\_\_\_\_  
installed in \_\_\_\_\_

| Effect or Fault                                            | Fuzzy Rate | Confused Rate | Blind Rate | Working months |
|------------------------------------------------------------|------------|---------------|------------|----------------|
| Lost power                                                 |            |               |            |                |
| Inlet or outlet valve blocked (positive displacement pump) |            |               |            |                |
| Piston blocked (positive displacement pump)                |            |               |            |                |
| Rising vibration                                           |            |               |            |                |
| Human                                                      |            |               |            |                |
| Worn-out                                                   |            |               |            |                |
| Unknown                                                    |            |               |            |                |
| Others/describe _____                                      |            |               |            |                |
| General remarks _____                                      |            |               |            |                |

2.3 Air blower, type of actuator \_\_\_\_\_ Manufacturer \_\_\_\_\_  
 installed in \_\_\_\_\_

| Effect or Fault       | Fuzzy Rate | Confused Rate | Blind Rate | Working months |
|-----------------------|------------|---------------|------------|----------------|
| Lost power            |            |               |            |                |
| System blocked        |            |               |            |                |
| Human                 |            |               |            |                |
| Worn-out              |            |               |            |                |
| Unknown               |            |               |            |                |
| Not moving            |            |               |            |                |
| Others/describe _____ |            |               |            |                |
| General remarks _____ |            |               |            |                |

2.4 Mixer, type of actuator \_\_\_\_\_ installed in \_\_\_\_\_

| Effect or Fault                        | Fuzzy Rate | Confused Rate | Blind Rate | Working months |
|----------------------------------------|------------|---------------|------------|----------------|
| Lost power                             |            |               |            |                |
| Decreasing power in the motor          |            |               |            |                |
| Eccentric rotation or rising vibration |            |               |            |                |
| Human                                  |            |               |            |                |
| Worn-out                               |            |               |            |                |
| Unknown                                |            |               |            |                |
| Others/describe _____                  |            |               |            |                |
| General remarks _____                  |            |               |            |                |

### 3. Abnormal Process Conditions

In the following, you can find the questionnaire that we have put together for abnormal process conditions that you think might occur and/or have occurred in the SBR. Abnormal conditions are to be understood as process conditions that are not considered by control and that you consider to be outside of the normal operating conditions of your process.

Please provide one filled in questionnaire for each case of abnormal condition.

#### **Questionnaire (Template for each specific case)**

Abnormal Condition: (Name, short name)

1. Description
2. Description of observations or reasoning indicating the abnormal condition
3. Description of actual or possible operator action
4. Occurred or expected to occur in your EOLI dedicated reactor? (Yes/no/don't know)
5. Frequency or expected frequency of occurrence (low, medium, high)
6. Importance/criticality you would assign to this abnormal condition (1=low-5=high)
7. References or literature that you consider to be related to this abnormal condition

### Fault Occurrence Statistics for Device

| SENSORS                      |                             |                       |                          |                             | Uruguay    |                               |        |        | Italia  |                           |        |        | México  |                           |          |  | Francia |  |  |  |
|------------------------------|-----------------------------|-----------------------|--------------------------|-----------------------------|------------|-------------------------------|--------|--------|---------|---------------------------|--------|--------|---------|---------------------------|----------|--|---------|--|--|--|
| Fault                        | pH                          | Type                  | Type                     | Type                        | Type       | Fault Frequency Normalization |        |        |         | Fault Weighting           |        |        |         | Fault Vulnerability Index |          |  |         |  |  |  |
|                              |                             | Electrode             | InLab 412 <sup>2</sup>   | 720A <sup>2</sup>           |            | times / 6 months              |        |        |         | F=33.33 , C=66.66 , B=100 |        |        |         |                           |          |  |         |  |  |  |
|                              |                             | P - 6m                | P - 6m                   | P - 0.6m                    |            | Uruguay                       | Italia | México | Francia | Uruguay                   | Italia | México | Francia |                           |          |  |         |  |  |  |
| 1                            | Lost Power                  |                       |                          |                             |            | 0                             | 6      | 0      | 0       | 0                         | 0      | 100    | 0       | 0                         | 150.00   |  |         |  |  |  |
| 2                            | Transmitter Disconnected    |                       |                          |                             | F- 2 t/m   | 0                             | 0      | 12     | 0       | 0                         | 0      | 0      | 33.33   | 0                         | 99.99    |  |         |  |  |  |
| 3                            | Broken Transmitter          |                       |                          |                             | B- 2 t/m   | 0                             | 0      | 12     | 0       | 0                         | 0      | 100    | 0       | 300.00                    |          |  |         |  |  |  |
| 4                            | Dirty Membrane              |                       |                          |                             | F- 4 t/m   | 0                             | 0      | 24     | 0       | 0                         | 0      | 33.33  | 0       | 199.98                    |          |  |         |  |  |  |
| 5                            | Drift                       | F- 2 t/w              |                          |                             |            | 48                            | 0      | 0      | 0       | 33.33                     | 0      | 0      | 0       | 399.96                    |          |  |         |  |  |  |
| 6                            | Wom-Out                     |                       | F- 1 t/6m                |                             | F- 1 t/5y  | 0                             | 1      | 0.1    | 0       | 0                         | 33.33  | 33.33  | 0       | 9.17                      |          |  |         |  |  |  |
| 7                            | Human                       |                       | C- 1 t/w                 |                             |            | 0                             | 24     | 0      | 0       | 0                         | 66.66  | 0      | 0       | 399.96                    |          |  |         |  |  |  |
| 8                            | Unknown                     |                       | F- 5 t/h                 |                             |            | 0                             | 21600  | 0      | 0       | 0                         | 33.33  | 0      | 0       | 179982.00                 |          |  |         |  |  |  |
| Device Vulnerability Index = |                             |                       |                          |                             |            |                               |        |        |         |                           |        |        |         |                           | 22692.63 |  |         |  |  |  |
| Fault                        | Dissolved Oxygen            | Type                  | Type                     | Type                        | Type       | Fault Frequency Normalization |        |        |         | Fault Weighting           |        |        |         | Fault Vulnerability Index |          |  |         |  |  |  |
|                              |                             | Electrode             | COS 3s <sup>2</sup>      | COS4 COM 223 <sup>2,4</sup> |            | times / 6 months              |        |        |         | F=33.33 , C=66.66 , B=100 |        |        |         |                           |          |  |         |  |  |  |
|                              |                             | P - 6m                | P - 6m                   | P - 10m                     |            | Uruguay                       | Italia | México | Francia | Uruguay                   | Italia | México | Francia |                           |          |  |         |  |  |  |
| 1                            | Lost Power                  |                       | B- 1 t/m                 |                             |            | 0                             | 6      | 0      | 0       | 0                         | 0      | 100    | 0       | 150.00                    |          |  |         |  |  |  |
| 2                            | Dirty Membrane              | F- 2 t/d              | C- 1 t/h                 |                             | F- 1 t/w   | 360                           | 4320   | 24     | 0       | 33.33                     | 66.66  | 33.33  | 0       | 75192.48                  |          |  |         |  |  |  |
| 3                            | Cracked Membrane            | F- 1 t/3m             |                          |                             | B- 1 t/10m | 2                             | 0      | 0.6    | 0       | 33.33                     | 0      | 100    | 0       | 31.67                     |          |  |         |  |  |  |
| 4                            | Drift                       |                       |                          |                             | F- 1 t/w   | 0                             | 0      | 24     | 0       | 0                         | 0      | 33.33  | 0       | 199.98                    |          |  |         |  |  |  |
| 5                            | Wom-Out                     |                       | F- 1 t/6m                |                             |            | 0                             | 1      | 0      | 0       | 0                         | 33.33  | 0      | 0       | 8.33                      |          |  |         |  |  |  |
| 6                            | Human                       |                       | C- 3 t/w                 |                             |            | 0                             | 72     | 0      | 0       | 0                         | 66.66  | 0      | 0       | 1199.88                   |          |  |         |  |  |  |
| 7                            | Unknown                     |                       | B- 1 t/m                 |                             |            | 0                             | 6      | 0      | 0       | 0                         | 100    | 0      | 0       | 150.00                    |          |  |         |  |  |  |
| Device Vulnerability Index = |                             |                       |                          |                             |            |                               |        |        |         |                           |        |        |         |                           | 10990.33 |  |         |  |  |  |
| Fault                        | Temperature                 | Type                  | Type                     | Type                        | Type       | Fault Frequency Normalization |        |        |         | Fault Weighting           |        |        |         | Fault Vulnerability Index |          |  |         |  |  |  |
|                              |                             | Electrode             | Pt100 <sup>2</sup>       | Inc. in DOx Sensor          |            | times / 6 months              |        |        |         | F=33.33 , C=66.66 , B=100 |        |        |         |                           |          |  |         |  |  |  |
|                              |                             | P - 6m                | P - 6m                   |                             |            | Uruguay                       | Italia | México | Francia | Uruguay                   | Italia | México | Francia |                           |          |  |         |  |  |  |
| 1                            | Lost Power                  |                       | B- 1 t/m                 |                             |            | 0                             | 6      | 0      | 0       | 0                         | 100    | 0      | 0       | 150.00                    |          |  |         |  |  |  |
| 2                            | Dirty Electrical Connection |                       | B- 1 a 2 t/m             |                             |            | 0                             | 12     | 0      | 0       | 0                         | 100    | 0      | 0       | 300.00                    |          |  |         |  |  |  |
| Device Vulnerability Index = |                             |                       |                          |                             |            |                               |        |        |         |                           |        |        |         |                           | 225.00   |  |         |  |  |  |
| Fault                        | Level                       | Type                  | Type                     | Type                        | Type       | Fault Frequency Normalization |        |        |         | Fault Weighting           |        |        |         | Fault Vulnerability Index |          |  |         |  |  |  |
|                              |                             | 3 Metal Elect.        |                          | Level Switch <sup>2</sup>   |            | times / 6 months              |        |        |         | F=33.33 , C=66.66 , B=100 |        |        |         |                           |          |  |         |  |  |  |
|                              |                             | P - 6m                |                          |                             |            | Uruguay                       | Italia | México | Francia | Uruguay                   | Italia | México | Francia |                           |          |  |         |  |  |  |
| 1                            | Transmitter Disconnected    | B- 1 t/w              |                          |                             |            | 24                            | 0      | 0      | 0       | 100                       | 0      | 0      | 0       | 600.00                    |          |  |         |  |  |  |
| 2                            | Inappropriate Tank Ground   | B- 1 t/6m             |                          |                             |            | 1                             | 0      | 0      | 0       | 100                       | 0      | 0      | 0       | 25.00                     |          |  |         |  |  |  |
| 3                            | Sewage Flow Out of Reactor  | C- 1 t/2d             |                          |                             |            | 90                            | 0      | 0      | 0       | 66.66                     | 0      | 0      | 0       | 1499.85                   |          |  |         |  |  |  |
| 4                            | Sewage Reach Err. Level     | C- 1 t/d ~10%         |                          |                             |            | 180                           | 0      | 0      | 0       | 66.66                     | 0      | 0      | 0       | 2999.70                   |          |  |         |  |  |  |
| 5                            | Dirty Electrodes            | ?- 1 t/w              |                          |                             |            | 24                            | 0      | 0      | 0       | 33.33                     | 0      | 0      | 0       | 199.98                    |          |  |         |  |  |  |
| Device Vulnerability Index = |                             |                       |                          |                             |            |                               |        |        |         |                           |        |        |         |                           | 1064.91  |  |         |  |  |  |
| Fault                        | Flow Rate                   | Type                  | Type                     | Type                        | Type       | Fault Frequency Normalization |        |        |         | Fault Weighting           |        |        |         | Fault Vulnerability Index |          |  |         |  |  |  |
|                              |                             | Rotameter             |                          |                             |            | times / 6 months              |        |        |         | F=33.33 , C=66.66 , B=100 |        |        |         |                           |          |  |         |  |  |  |
|                              |                             | P - 6m                |                          |                             |            | Uruguay                       | Italia | México | Francia | Uruguay                   | Italia | México | Francia |                           |          |  |         |  |  |  |
| 0                            | No Fault                    |                       |                          |                             |            | 0                             | 0      | 0      | 0       | 0                         | 0      | 0      | 0       | 0.00                      |          |  |         |  |  |  |
| Device Vulnerability Index = |                             |                       |                          |                             |            |                               |        |        |         |                           |        |        |         |                           | 0.00     |  |         |  |  |  |
| ACTUATORS                    |                             |                       |                          |                             |            |                               |        |        |         |                           |        |        |         |                           |          |  |         |  |  |  |
| Fault                        | Servo-Valve                 | Type                  | Type                     | Type                        | Type       | Fault Frequency Normalization |        |        |         | Fault Weighting           |        |        |         | Fault Vulnerability Index |          |  |         |  |  |  |
|                              |                             | Solenoid <sup>1</sup> |                          |                             |            | times / 6 months              |        |        |         | F=33.33 , C=66.66 , B=100 |        |        |         |                           |          |  |         |  |  |  |
|                              |                             | P - 6m                |                          |                             |            | Uruguay                       | Italia | México | Francia | Uruguay                   | Italia | México | Francia |                           |          |  |         |  |  |  |
| 1                            | Not Closing Fully           | C- 1 t/w              |                          |                             |            | 24                            | 0      | 0      | 0       | 66.66                     | 0      | 0      | 0       | 399.96                    |          |  |         |  |  |  |
| 2                            | Not Opening Fully           | C- 1 t/w              |                          |                             |            | 24                            | 0      | 0      | 0       | 66.66                     | 0      | 0      | 0       | 399.96                    |          |  |         |  |  |  |
| Device Vulnerability Index = |                             |                       |                          |                             |            |                               |        |        |         |                           |        |        |         |                           | 399.96   |  |         |  |  |  |
| Fault                        | Pump                        | Type                  | Type                     | Type                        | Type       | Fault Frequency Normalization |        |        |         | Fault Weighting           |        |        |         | Fault Vulnerability Index |          |  |         |  |  |  |
|                              |                             | Penstatic             | Peristaltic <sup>3</sup> | Peristaltic <sup>6</sup>    |            | times / 6 months              |        |        |         | F=33.33 , C=66.66 , B=100 |        |        |         |                           |          |  |         |  |  |  |
|                              |                             | P - 6m                | P - 6m                   | P - 10m                     |            | Uruguay                       | Italia | México | Francia | Uruguay                   | Italia | México | Francia |                           |          |  |         |  |  |  |
| 1                            | Lost Power                  |                       | B- 1 t/m                 |                             |            | 0                             | 6      | 0      | 0       | 0                         | 100    | 0      | 0       | 150.00                    |          |  |         |  |  |  |
| 2                            | Line Clogging               | ?- 1 t/6m             |                          |                             |            | 1                             | 0      | 0      | 0       | 33.33                     | 0      | 0      | 0       | 8.33                      |          |  |         |  |  |  |
| 3                            | Wom-Out                     |                       | B- 1 t/6m                |                             |            | 0                             | 1      | 0      | 0       | 0                         | 100    | 0      | 0       | 25.00                     |          |  |         |  |  |  |
| 4                            | Human                       | C- 1 t/6m             |                          |                             | F- 1 t/4m  | 1                             | 0      | 1.5    | 0       | 66.66                     | 0      | 33.33  | 0       | 29.16                     |          |  |         |  |  |  |
| 5                            | Unknown                     |                       |                          |                             | F- 1 t/m   | 0                             | 0      | 6      | 0       | 0                         | 0      | 33.33  | 0       | 50.00                     |          |  |         |  |  |  |
| Device Vulnerability Index = |                             |                       |                          |                             |            |                               |        |        |         |                           |        |        |         |                           | 52.50    |  |         |  |  |  |
| Fault                        | Air Blower                  | Type                  | Type                     | Type                        | Type       | Fault Frequency Normalization |        |        |         | Fault Weighting           |        |        |         | Fault Vulnerability Index |          |  |         |  |  |  |
|                              |                             | Rec. Air Comp.        | Mem. Air Comp.           | Air Compressor              |            | times / 6 months              |        |        |         | F=33.33 , C=66.66 , B=100 |        |        |         |                           |          |  |         |  |  |  |
|                              |                             | P - 6m                | P - 6m                   | P - 10m                     |            | Uruguay                       | Italia | México | Francia | Uruguay                   | Italia | México | Francia |                           |          |  |         |  |  |  |
| 1                            | Lost Power                  | B- 1 t/6m             | B- 1 t/m                 |                             |            | 1                             | 6      | 0      | 0       | 100                       | 100    | 0      | 0       | 175.00                    |          |  |         |  |  |  |
| 2                            | Blocked Diffuser            | F- 1 t/d              |                          |                             |            | 180                           | 0      | 0      | 0       | 33.33                     | 0      | 0      | 0       | 1499.85                   |          |  |         |  |  |  |
| 3                            | Broken Air Line             | ?- 1 t/6m             |                          |                             |            | 1                             | 0      | 0      | 0       | 33.33                     | 0      | 0      | 0       | 8.33                      |          |  |         |  |  |  |
| 4                            | Wom-Out                     |                       | B- 1 t/6m                |                             |            | 0                             | 1      | 0      | 0       | 0                         | 100    | 0      | 0       | 25.00                     |          |  |         |  |  |  |
| 5                            | Unknown                     |                       |                          |                             | F- 1 t/m   | 0                             | 0      | 6      | 0       | 0                         | 0      | 33.33  | 0       | 50.00                     |          |  |         |  |  |  |
| Device Vulnerability Index = |                             |                       |                          |                             |            |                               |        |        |         |                           |        |        |         |                           | 351.64   |  |         |  |  |  |
| Fault                        | Mixer                       | Type                  | Type                     | Type                        | Type       | Fault Frequency Normalization |        |        |         | Fault Weighting           |        |        |         | Fault Vulnerability Index |          |  |         |  |  |  |
|                              |                             | Helix Impeller        | Mec. Var-Speed           |                             |            | times / 6 months              |        |        |         | F=33.33 , C=66.66 , B=100 |        |        |         |                           |          |  |         |  |  |  |
|                              |                             | P - 6m                | P - 6m                   |                             |            | Uruguay                       | Italia | México | Francia | Uruguay                   | Italia | México | Francia |                           |          |  |         |  |  |  |
| 1                            | Lost Power                  |                       | B- 1 t/m                 |                             |            | 0                             | 6      | 0      | 0       | 0                         | 100    | 0      | 0       | 150.00                    |          |  |         |  |  |  |
| Device Vulnerability Index = |                             |                       |                          |                             |            |                               |        |        |         |                           |        |        |         |                           | 150.00   |  |         |  |  |  |
| Fault                        | Mass Flow Controller        | Type                  | Type                     | Type                        | Type       | Fault Frequency Normalization |        |        |         | Fault Weighting           |        |        |         | Fault Vulnerability Index |          |  |         |  |  |  |
|                              |                             |                       |                          | GFC37 <sup>6</sup>          |            | times / 6 months              |        |        |         | F=33.33 , C=66.66 , B=100 |        |        |         |                           |          |  |         |  |  |  |
|                              |                             |                       |                          | P - 4y                      |            | Uruguay                       | Italia | México | Francia | Uruguay                   | Italia | México | Francia |                           |          |  |         |  |  |  |
| 1                            | Wom-Out                     |                       |                          | B- 1 t/3y                   |            | 0                             | 0      | 0.1666 | 0       | 0                         | 0      | 100    | 0       | 4.17                      |          |  |         |  |  |  |
| Device Vulnerability Index = |                             |                       |                          |                             |            |                               |        |        |         |                           |        |        |         |                           | 4.17     |  |         |  |  |  |

General Remarks:

- There are 6 solenoid valves operating in each reactor. One of them, in each reactor, fails 1 t/w.
- This sensor is cleaned and calibrated 1 t/w.
- Pipes cleaning 1 t/m.
- Drift appears when the membrane is dirty. Membrane change is done 1 t/10m of operation.
- The piping tube must be replaced in average 1 t/15d. When the tubing is changed the pump must be recalibrated.
- One week before the failure, the valve do not closed fully and a small leak of air was observed during decantation.

Notation:

- P; Indicates the period during the equipment has been used.  
t; Times (occurrence).  
d, w, m, y; Respectively means, Days, Weeks, Moths and Years.  
F, C, B, ?; Respectively means, Fuzzy, Confuse, Blind and Not Indicated.